Chapter 2

Engineering Costs and Cost Estimating
COSTS

- Fixed and Variable
- Marginal and average
- Direct and Indirect
- Sunk and Opportunity
- Recurring and Non-recurring
- Incremental
- Cash and Book
- Life-Cycle
COSTS

- **Fixed Costs**
  They are constant or unchanging regardless of the level of output or activity
  - *e.g.* Costs for factory floor space stays the same regardless of the production quantity, number of employees, and the level of work-in-process.

- **Variable Costs**
  They vary with the level of output or activity
  - *e.g.* Labor costs since they depend on the number of employees
COSTS

- **Marginal Cost**
  The variable cost for one more unit
  - *Used to decide whether the additional unit should be made, purchased, or enrolled in.*

- **Average Cost**
  The total cost divided by the number of units
  - *Used to attain an overall cost picture of the investment on a per unit basis.*
Example

A university charges students a fixed cost for 12 to 18 hours and a cost per credit hour for each credit hour over 18 (page 28)

- Variable cost for students taking > 18 hours.
- If a student is enrolled for 12-17 hours, adding one more is free; i.e. the marginal cost is $0
- If a student is taking 18 hours, then the marginal cost equals the variable cost of one more hour.
- Cost of 12 to 18 hours is $1800. Overload credits cost $120/hour.

<table>
<thead>
<tr>
<th></th>
<th>12 hours</th>
<th>18 hours</th>
<th>21 credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average cost</td>
<td>$150</td>
<td>$100</td>
<td>102.86</td>
</tr>
<tr>
<td>Marginal cost</td>
<td>$0</td>
<td>$120</td>
<td>$120</td>
</tr>
</tbody>
</table>
COSTS

- Total cost = Total fixed cost + Total variable cost
Example 2-1

DK is thinking of chartering a bus to take people to an event in a large city. He is providing transportation, tickets to the event, and refreshments on the bus. He predicted the following expenses:

- Bus rental: $80
- Event ticket: $12.5 per person
- Gas expense: $75
- Refreshments: $7.5 per person
- Other fuels: $20
- Bus driver: $50

Total fixed costs and total variable costs?

- **Fixed costs** will be incurred regardless of how many people sign up for the trip. Total fixed costs = $80 + $75 + $20 + $50 = $225.

- **Variable costs** depend on how many people sign up for the trip. Total variable costs = $12.5 + $7.5 = $20 per person.
Example 2-2

Develop a formula for the total cost and evaluate the potential to make money from the trip. DK believes that he could attract 30 people at $35 per ticket.

\[
\text{Total cost} = \text{total fixed cost} + \text{total variable cost}
\]

\[
\text{Total cost} = 225 + 20x \quad x = \text{number of people on the trip}
\]

\[
\text{Total revenue} = (\text{ticket price})(x) = 35x
\]

\[
\text{Total profit} = (\text{Total revenue}) - (\text{Total costs}) = 35x - (225 + 20x)
\]

\[
= 15x - 225
\]

At \( x = 30 \)

\[
\text{Total profit} = 35 \times 30 - (225 + 20 \times 30) = 225
\]

So, if 30 people go for the trip, DK will make a net profit of $225
Example

In the chartered bus example, find the number of people at which costs and revenues are equal

Total cost = total revenue

\[225 + 20x = 35x\]

\[X = 15 \text{ people}\]

\[x = 15 \text{ is the point that divides the regions into profit or loss.}\]

If \(x > 15\), DK will make money

If \(x < 15\), DK will lose money

\[x = 15 \text{ is called the breakeven point.}\]
Breakeven chart for DK chartered bus

Total revenue
\[ y = 35x \]

Total cost
\[ y = 20x + 225 \]

Breakeven point

Customers

Cost
Sunk Costs

- Money already spent as a result of a past decision.
- Should be disregarded in our engineering economic analysis *(because current decision cannot change the past)*
- As economists, we deal with present and future opportunities

**Example**

Share prices declined from $15 to $10 over the last 12 months.
- The $15 is a sunk cost that has no influence on present opportunities
- Current decisions must focus on the current price ($10), as well as the future price potential.

**Example**

Laptop for $2000 three years ago. Nowadays, the most that anyone would pay you for the laptop is $400.
- The $2000 is a sunk cost that has no influence on your present opportunity to sell the laptop
- The $400 is called the current market value.
Opportunity Cost

- It is the benefit that is forgone by engaging a business resource in a chosen activity instead of engaging that same resource in the forgone activity.

  *(A business resource can be equipment, money, manpower, or any other resource)*

**Example**

Friends invited you to Europe. You calculated the cost of the 10-week trip to be $3000. You have the money and decided to go.

- By taking the trip, you give up the opportunity to earn $5000 as a summer intern.
- True cost = $3000 + opportunity cost of $5000 = $8000
Example 2-3

A distributor purchased a lot of old pumps 3 years ago. Newer pumps are now available in the market due to advances made in technology.

<table>
<thead>
<tr>
<th>Comment</th>
<th>Purchase price 3 yrs ago</th>
<th>Storage costs to date</th>
<th>Distributor's list price 3 yrs ago</th>
<th>Current list price of new pumps</th>
<th>Amount offered for the old pumps 2 yrs ago</th>
<th>Current price the old pumps would bring</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Sunk cost</td>
<td>$ 7,000</td>
<td>$ 1,000</td>
<td>$ 9,500</td>
<td>$12,000</td>
<td>$ 5,000</td>
<td>$ 3,000</td>
</tr>
<tr>
<td>- Sunk cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Too old</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Misleading</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Forgone opportunity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Market value</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pricing manager’s opinion: $8000 (to at least recover the cost)
Recurring and Nonrecurring Costs

- **Recurring Costs**
  - Costs referring to any expense that is known, anticipated, and occurs at regular intervals.
  - Modeled as cash flows that occur at regular intervals.
  - e.g. resurfacing a highway, annual operation and maintenance expenses

- **Nonrecurring Costs**
  - One-of-a-kind expenses that occur at irregular intervals.
  - Difficult to plan for or anticipate from a budgeting perspective, both in terms of timing and size.
  - You don’t need to worry about paying them again and again.
  - e.g. fire or theft losses, installing a new machine, emergency maintenance expenses, moving expenses.
Incremental Costs

- When making a choice among competing alternatives, focus should be placed on the *differences* between those alternatives, i.e. incremental costs, not on the costs that are the same.
What incremental costs would you incur if you chose model B instead of the less expensive model A? Model B has more features and a higher purchase price.

<table>
<thead>
<tr>
<th>Cost Items</th>
<th>Model A</th>
<th>Model B</th>
<th>Incremental Cost of B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase price</td>
<td>$10,000</td>
<td>$17,500</td>
<td>$7,500</td>
</tr>
<tr>
<td>Installation cost</td>
<td>$3,500</td>
<td>$5,000</td>
<td>$1,500</td>
</tr>
<tr>
<td>Annual maintenance cost</td>
<td>$2,500</td>
<td>$750</td>
<td>-$1,750/yr</td>
</tr>
<tr>
<td>Annual utility expense</td>
<td>$1,200</td>
<td>$2,000</td>
<td>$800/yr</td>
</tr>
<tr>
<td>Disposal cost after useful life</td>
<td>$700</td>
<td>$500</td>
<td>-$200</td>
</tr>
</tbody>
</table>
Cash Costs versus Book Costs

**Cash Costs**
- A cash cost requires the cash transaction of dollars “out of one person’s pocket” into “the pocket of someone else”.
  - *i.e. you are incurring a cash cost or cash flow.*
  - *Cash costs and cash flows are the basis for engineering economic analysis*

**Book Costs**
- They are cost effects from past decisions that are recorded in the books (accounting books). They are costs reflected in the accounting system only.
  - *Don’t represent cash flows*
  - *Not included in the engineering economic analysis*

**Example**: You might use *Edmond’s Used Car Guide* to conclude the *book value* of your car is $6,000. The book value can be thought of as the *book cost*. If you actually sell the car to a friend for $5,500, then the *cash cost* to your friend is $5,500.
Life-Cycle Costs

Similar to humans; goods, products, and services designed by engineers progress through a life cycle.

Typical Life Cycle

1. Needs definition
2. Conceptual design
3. Detailed design
4. Production
5. Operation use
6. Decline and retirement
**Life-Cycle Costs**

- **Life-cycle costing**: Refers to the concept of designing products, goods, and services with a full and explicit recognition of the associated costs over the various phases of their life cycles.

- Engineers should consider all life-cycle costs when designing products and the systems that produce them.

- **Life-cycle cost**: It is the summation of all costs related to a product, structure, system, or service during its life span. All amounts are expressed in dollars and they must be time equivalent.

- This time-equivalency is important because a dollar today is worth more than a dollar next year because of the interest (profit) it can earn.
Cumulative life-cycle costs committed and dollars spent

Note: 70-90% of all costs are set during the design phases. At the same time only 10-30% of cumulative life-cycle costs have been spent.
Life-Cycle Costs

- **Two key concepts in life-cycle costing**
  - The later design changes are made, the higher the costs
  - Decisions made early in the life cycle tend to lock in costs that are incurred later.
Life-Cycle Design Change Costs and Ease of Change

![Graph showing the relationship between project phase and ease or cost of change.](image)

- **Ease of Changing Design**
- **Cost of Design Changes**

Project Phase:
- Needs Definition
- Conceptual Design
- Detailed Design
- Production
- Operational Use
- Decline/Retirement

Note: Downstream changes vs. upstream changes
Costs Estimating

- Difficult because future is unknown

- It is the foundation of economic **analysis**
  - If poor data are used, the analysis will be grossly inaccurate – no matter how detailed your economic analysis was. This means that it is crucial to make careful estimates.
  - In other words: The outcome is only as good as the quality of the numbers used.
Costs Estimating

Three Types of Estimate:

- Rough Estimate
  - For high-level planning.
  - To determine the macrofeasibility.
  - Used in a project’s initial planning phases.
  - Accuracy is -30% to +60%.

- Semidetailed Estimate
  - For budgeting purposes at a project’s conceptual or preliminary design stages.
  - Accuracy is -15% to +20%.

- Detailed Estimate
  - Used during the detailed design and contract bidding phases.
  - Made from detailed quantitative models, blueprints, product specification sheets, and vendor quotes.
  - Accuracy is -3% to +5%.

The more detailed you are, the more resources (people, time, money) you will need. So, be careful to justify the resources you spent (e.g. detailed estimate for unfeasible alternatives!)
Estimating Models

- Per-Unit Model
- Segmenting Model
- Cost indexes
- Power-sizing Model
Estimating Models

Per-Unit Model

- Uses a per unit factor (e.g. cost per square meter)
- Commonly used in the construction industry
- Other examples: Gasoline cost per 1 km or how many km per 1L of gas
Estimating Models

Segmenting Model
- Estimate is segmented into its individual components
- Then the estimates are aggregated back together.
Cost Indexes

- Cost indexes are dimensionless numerical values that reflect historical change in costs.

\[
\text{Cost at time A} \quad = \quad \text{Index value at time A} \\
\text{Cost at time B} \quad = \quad \text{Index value at time B}
\]
Example 2-7

Miriam is interested in estimating the annual labor and material costs for a new production facility. She obtained the following data:

- **Labor costs:**
  - Labor cost index value was 124 ten years ago and is 188 today
  - Annual labor costs for a similar facility were $575,500 ten years ago

- **Material costs**
  - Material cost index value was at 544 three years ago and is 715 today
  - Annual material costs for a similar facility were $2,455,000 three years ago

\[
\frac{\text{Annual Cost today}}{\text{Index value today}} = \frac{\text{Annual cost 10 yrs ago}}{\text{Index value 10 yrs ago}}
\]

Annual cost today = \( \frac{188}{124} \times \$575,500 \) = $871,800
Power-Sizing Model

- Used to estimate the costs of industrial plants and equipment
- It *scales up* or *scales down* costs
  - Would it cost twice as much to build the same facility with double the capacity → *It is unlikely*

\[
\frac{\text{Cost of equipment A}}{\text{Cost of equipment B}} = \left( \frac{\text{Size or capacity of equipment A}}{\text{Size or capacity of equipment B}} \right)^x
\]

Where \( x \) is the power-sizing exponent

- If \( x=1 \) → linear cost-size relationship
- If \( x>1 \) → diseconomies of scale
- Usually \( x<1 \) → economies of scale

(Look at *table 2-1* in your text for power-sizing exponent values)
Example 2-8

Miriam needs to estimate the cost of a 2500 ft$^2$ heat exchange system.

- $50,000 for a 1000 ft$^2$ heat exchanger 5 yrs ago
- Power sizing exponent $x = 0.55$
- Five years ago cost index was 1306; it is 1487 today

\[
\text{Cost of 2500 ft}^2 \text{ equipment} = \left( \frac{2500 \text{ ft}^2}{1000 \text{ ft}^2} \right)^{0.55} \\
\text{Cost of 1000 ft}^2 \text{ equipment} = \left( \frac{1000 \text{ ft}^2}{2500 \text{ ft}^2} \right)
\]

\[
\text{Cost of the 2500 ft}^2 \text{ equipment (five yrs ago)} = \left( \frac{2500}{1000} \right)^{0.55} \times 50,000 = $82,800
\]

\[
\text{Equipment cost today} = $82,800 \times \frac{1487}{1306} = $94,300
\]
Estimating Benefits

- An important part of the economic analysis that should not be overlooked
- Similar to concepts and models used in estimating costs
- Benefits are more likely to be overestimated while costs are more likely to be underestimated
- Benefits continue in the future while costs are incurred in the near future
Cash Flow Diagrams (CFD)

- Costs & benefits of engineering products occur over time
  - Use *Cash Flow Diagram* to represent them.
- CFD illustrates the size, sign, and timing of individual cash flows.
- Use one perspective: One person’s cash outflow is another person’s inflow